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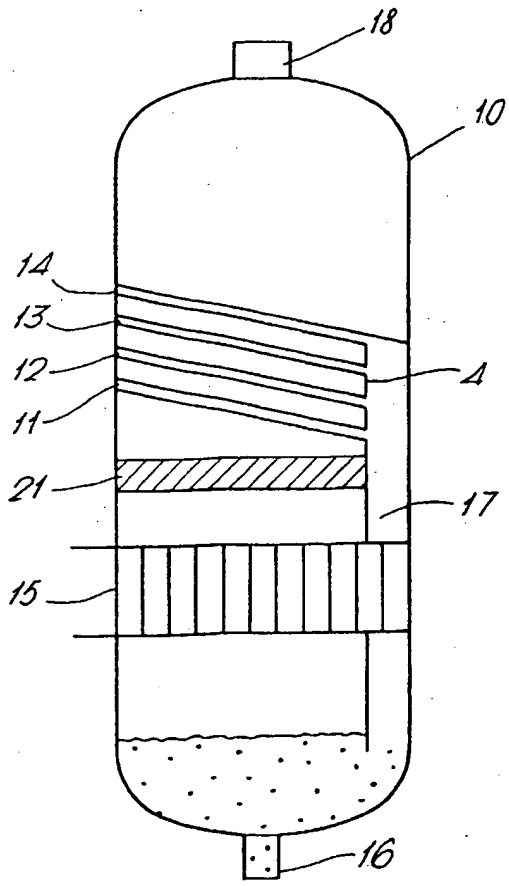
[Continued on next page]

(54) Title: GAS-LIQUID SEPARATOR



(57) Abstract: Gas-liquid separator comprising two or more vertically spaced rows (11-14) of parallel horizontally spaced upwardly facing gutters, said gutters (4) having an upwardly extending gutter wall, wherein the upper end of the gutter wall is provided with a U-turn deflector.

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GAS-LIQUID SEPARATOR

The invention is related to a gas-liquid separator comprising two or more vertically spaced rows of parallel horizontally spaced upwardly facing gutters, said gutters having an upwardly extending gutter wall.

Such a gas-liquid separator is known from US-A-4361469 and is also described in US-A-5695548 and in Trans IChemE, vol. 77, Part A, October, pages 619-626. According to US-A-4361469 the disclosed gas-liquid separator consists of a plurality of vertically spaced rows or levels of horizontally spaced parallel gutters. The individual gutters are each in the form of an elongate open top gutter of rectangular cross section having a bottom and side walls. The gutters are spaced apart vertically and horizontally. In use an up-flowing gas-liquid mixture having entrained liquid droplets carried thereby will vertically pass the rows of gutters. Because of the changes in flow direction, due to the particular gutter configuration, the gas-liquid mixture is thrust against the gutters, thereby separating the liquid droplets from the mixture. The liquid thereby falls into the open upper side of the gutters. Because the gutters are somewhat tilted the liquid will flow to the lower end of the gutter, at which point the liquid can be collected and transported to a lower level without being de-entrained by the upwardly moving gas and liquid.

A disadvantage of the gas-liquid separator is that the liquid separation is not satisfactory. The object of the present invention is to improve the separation efficiency of the gas-liquid separator as described above.

This objective is achieved by the following gas-liquid separator. Gas-liquid separator comprising two or more vertically spaced rows of parallel horizontally spaced upwardly facing gutters, said gutters having an upwardly extending gutter wall, wherein the upper end of the gutter wall is provided with a U-turn deflector.

It has been found that the gas-liquid separator according to the invention shows an improved separation efficiency as compared to the gas-liquid separator as disclosed in the prior art. Without being bound to the following theory applicant believes that the improved separation efficiency is attributed to the fact that droplets which accumulate on the outside wall of the gutter will be less re-entrained at the upper end of the gutter wall by the upwardly moving gas because of the presence of the U-turn deflectors. Additionally some secondary gas will also be deflected by the U-turn deflector, thereby positively influencing the flow of liquid from the outside gutter wall into the interior of the gutter.

The gas-liquid separator according to the present invention may find application as a stand alone separator application, wherein the separator forms part of a vessel provided with a gas-liquid inlet and a liquid outlet at its lower end and a gas outlet at its upper end and means to transport the separated liquid downwards from the gutters to the liquid outlet, such that the downwards moving liquid is not obstructed by up-flowing gas-liquid mixture. Such a means can be a downcomer positioned near the vessel wall. To further improve the gas-liquid separation the vessel may be suitably provided with a coalescer below the gutter device. The gutter separator will be provided with means to transport the liquid downwards to the liquid outlet. The gas-liquid inlet may be a device, which enhances a first gas-liquid separation

as for example a Shell Schoepentoeter (Shell Schoepentoeter is a trademark). GB-A-1119699 describes such a Shell Schoepentoeter.

The gas-liquid separator according to the present invention may also be suitably used in a gas-liquid contacting column, wherein gas and liquid are contacted counter-currently. Preferred gas-liquid contacting columns are distillation and absorption columns. In absorption processes a downwardly moving liquid is contacted with a upwardly moving gas and one or more components is transferred from the gas to the liquid or vice versa. In a distillation process one or more components are separated from a feed due to differences in their boiling points. In a distillation process the feed is typically supplied to an intermediate position in the column, wherein trays are present above and below said inlet position. Such a column is further provided with reboiler, condensation and reflux means. The preferred Column for counter-currently contacting gas and liquid has inlets and outlets for fluids, is provided with a plurality of horizontal contact trays arranged axially spaced apart in the column, each contact tray being provided with passages, and which column is further provided with a plurality of horizontal separation trays comprising the separator according to the present invention and means for removing liquid from the separation tray to a lower position, each separation tray being arranged above a contact tray. The configuration of separation and contacting trays is known from the aforementioned US-A-4361469 and US-A-5695548. The column provided with the improved separation device according to the invention will achieve a better performance. The improvement in performance is that the maximum gas flow rate through the column is higher, wherein the maximum

gas flow rate is the gas flow rate at which entrainment of liquid by the upwards flowing gas starts.

The gas-liquid separator may also be advantageously be used as separator tray in the gas-liquid contacting column of EP-A-751808. This column is provided with a plurality of contact trays, wherein above a contact tray a separation tray is provided. Said separation tray is provided with swirl tubes to achieve the gas-liquid separation. This tray is also referred to as a "swirl deck". The present separator has the advantage over the swirl deck in that it is much more simple to fabricate, requires less column height to install and has a lower pressure drop when in use.

Preferably the gas-liquid separator according to the invention comprises of two or more vertically spaced rows of gutters. In a gas-liquid separator application the maximum number of rows will be determined by the required separation efficiency required from the gutter separator according to the invention. If the gutter separator is used in gas-liquid contacting column, as described above in more detail, the number of rows will preferably be from 2 to 8, more preferably from 2 to 4. More rows are possible. However this would require more column height.

The gutters of one row may run parallel or non-parallel to the gutters of a next or further vertically spaced row. For fabrication reasons the gutters of the different vertically spaced rows will suitably run parallel with respect to each other. The gutters may have any cross-sectional design, provided that they are open at its upper side and closed at its lower side and provided with a side-wall which terminates at its upper end. Examples of suitable cross-sectional designs are the U-form, the V-form and the designs disclosed in US-A-4361469. The dimensions of the gutters and the

distance between the gutters in one row and the distance between rows may be as disclosed in US-A-4361469.

The gutters may be positioned horizontally but are preferably tilted such that the liquid can more freely flow to the side of the separator as for example described in US-A-4361469. Preferably the gutters are not tilted to much because then the separator would become to high. An optimal angle can be easily determined by one skilled in the art based on these considerations. The U-turn deflector may run along the entire gutter wall or may be present at regular intervals. Preferably the U-turn deflector is present along substantially the entire length of both of the upwardly extending gutter walls.

The design of the U-turn deflector should be such that re-entrainment of liquid flowing upwards on the outer wall of the gutter is avoided and that this liquid and the secondary gas is guided into the gutter. For this reason the U-turn deflector is spaced away from the upper end of the gutter walls, thereby allowing an opening between the U-turn deflector and the upper end of the gutter wall for passage of liquid and secondary gas. The U-turn deflector can have a curved or hooked design. The deflector can be fixed to the gutter by means of for example welding.

The invention will be further illustrated by making use of Figure 1-6.

Figure 1 shows a cross-sectional view of three vertically spaced rows (1, 2, 3) of gutters (4). The gutters (4) have a boxed design which gutter has two upwardly extending elongated gutter walls, each wall provided with a U-turn deflector (5).

Figure 2 shows an individual boxed design gutter (4) provided with U-turn deflector (5). Figure 3 shows a V-shaped gutter (4) provided with U-turn deflector (5).

Figure 4 shows how a stream (6) of gas and liquid droplets will flow along the gutter (4). As shown droplets accumulate on the gutter wall as a liquid film (8) which flows upwards along the gutter wall. The U-turn deflectors (5) avoid that this liquid film re-entrains from the gutter. Instead the liquid from the film flows into the gutter via (9). Some secondary gas (7) enhances this flow.

Figure 5 shows a gas-liquid separator provided with the gutter separator according to the invention. The separator vessel (10) is provided with 4 vertically spaced rows (11, 12, 13, 14) of parallel and horizontally spaced tilted gutters (4). The vessel is also provided with an inlet device (15) according to Figure 4 of GB-A-1119699 to supply the gas liquid mixture, a liquid outlet (16) fluidly connected to the lower end of the gutters (4) via downcomer (17) and a gas outlet (18). Below the gutters a coalescer (21) is provided to increase liquid droplet size in the up-flowing gas-liquid mixture.

Figure 6 shows part of a counter-current gas-liquid contacting column (22) provided with horizontal contact trays (23), (24) and (25) arranged axially spaced apart in the column (22). The horizontal contact trays (23), (24) and (25) are so-called sieve trays. A sieve tray is a flat plate provided with passages in the form of holes in it; for the sake of clarity the holes in the plates have not been referred to by reference numerals. For the present invention the design of the contact tray is not critical. For example instead of a sieve tray, a contacting tray comprising gutters as described in the aforementioned US-A-5695548 may also be used. The horizontal contact trays (23), (24) and (25) are provided with downcomers (26), (27) and (28) respectively. Such a downcomer, which is not disclosed in the aforementioned US-A-4361469, has been found advantageous to achieve a

easy start-up of such a column. The downcomer (28) opens below the contact tray (25) onto the next lower contact tray (not shown), and so on. In practice the downcomer pertaining to lowermost separation tray of the column will open into the lower part of the column.

The column (22) is provided with a gas inlet and a liquid outlet arranged in its lower end and a liquid inlet and a gas outlet arranged in its upper end; the gas inlet, the liquid outlet, the liquid inlet and the gas outlet are not shown in Figure 6.

Column (22) is furthermore provided with horizontal separation trays (29), (30) and (31), each separation tray (29), (30) and (31) being arranged below a contact tray (23), (24) and (25). The separation trays (29), (30) and (31) consist of three vertically spaced rows of gutters (4). The U-turn deflector are present but not shown in this Figure for clarity reasons. Each separation tray (29), (30) and (31) is furthermore provided with means for removing liquid from the separation tray in the form of a downcomer (32), (33) and (34). The downcomer (32) of separation tray (29) opens via downcomer (27) on the second contact tray (25) below the separation tray (24), and so on.

The invention will be illustrated with the following non-limiting examples.

Example 1

A test set up (35) as illustrated in Figure 7 was used to test the separator according to the invention. In this test set up water was supplied at a rate of 4.25 m^3 per hour via (36) to a tray (37) provided with atomisers (38). Air was supplied from below the tray to atomisers (38) resulting in an upwardly moving water-droplets/air mixture (39). Water was separated from this mixture (39) in U-gutter separation deck (40). Separation deck (40)

consisted of 4 vertically spaced rows of gutters. The number of parallel oriented gutters was 3, 4, 3, and 4 respectively, counting from below. The V-shaped gutters were provided with an U-turn deflector along the entire length of both upper ends of the upwardly pointed gutter walls. The separated water was collected in vessel (41) and air poor in water (42) was allowed to move upwards above separation deck (40). The ratio of water led into the column to the amount of water collected in vessel (41) was defined as the separation efficiency (%).

The volume of air was varied and the separation efficiency at different load factors was measured. The load factor (λ_{BA}) is here defined as:

$$\lambda_{BA} = \frac{Q_g}{A_{BA}} \sqrt{\frac{\rho_G}{\rho_L - \rho_G}}$$

wherein Q_g is the volume of gas per second (m^3/s), A_{ba} is the area of the test set up which is covered by the separator deck (40), ρ_G is the gas density (kg/m^3) and ρ_L is the liquid density(kg/m^3). Figure 8 shows that for different load factor values between 0.05 and 0.19 m/s excellent separation efficiencies of above 80% and even above 90% are achieved (circles in Fig. 8 represent results of Example 1).

Comparative Experiment A

Example 1 was repeated except that the U-turn deflectors were removed resulting in a separation device as disclosed in US-A-4361469. The results are also presented in Figure 8 as the triangles. From the results it can be concluded that the gas-liquid separator according to the present invention shows improved separation efficiency when compared to the state of the art separator.

Example 2

Example 1 was repeated except that water was supplied at a rate of 7.2 m^3 per hour. The results are presented in Figure 9 as the circles.

Comparative Experiment B

Example 2 was repeated except that the U-turn deflectors were removed resulting in a separation device as disclosed in US-A-4361469. The results are also presented in Figure 9 as the triangles. From the results it can be concluded that the gas-liquid separator according to the present invention shows improved separation efficiency when compared to the state of the art separator at the high liquid load as in Example 2 and Comparative Experiment B.

CLAIMS

1. Gas-liquid separator comprising two or more vertically spaced rows of parallel horizontally spaced upwardly facing gutters, said gutters having an upwardly extending gutter wall, wherein the upper end of the gutter wall is provided with a U-turn deflector.

2. Separator according to claim 1, wherein the gutters are tilted.

3. Separator according to any one of claims 1-2, wherein the gutters have a V-shaped cross-sectional design.

4. Gas-liquid separator vessel provided with a gas-liquid inlet and a liquid outlet at its lower end and a gas outlet at its upper end and the gutter separator according to any one of claims 1-3 between said gas-liquid inlet and gas outlet and further provided with means to transport separated liquid from said gutter separator to the liquid outlet.

5. Gas-liquid separator vessel according to claim 4, wherein a coalescer is present between the gas-liquid inlet and the gutter separator.

6. Gas-liquid contacting column provided with a plurality of horizontal contact trays arranged axially spaced apart in the column, wherein above a contact tray a gutter separator according to any one of claims 1-3 is present, said gutter separator further provided with means for removing liquid to a lower position in the column.

7. Gas-liquid contacting column according to claim 6, wherein a contact tray is provided with a downcomer to transport liquid to a next lower contact tray.

8. Use of a column according to any one of claims 5-7 as a distillation or absorption column.

Fig.1.

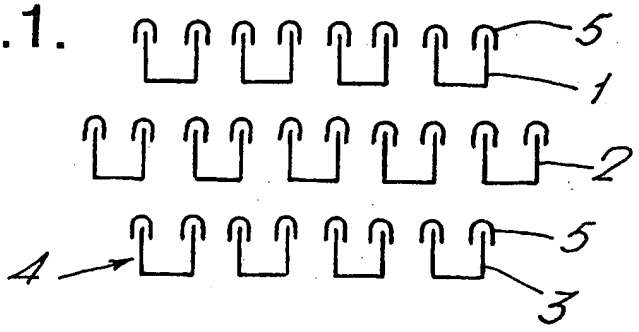


Fig.2.

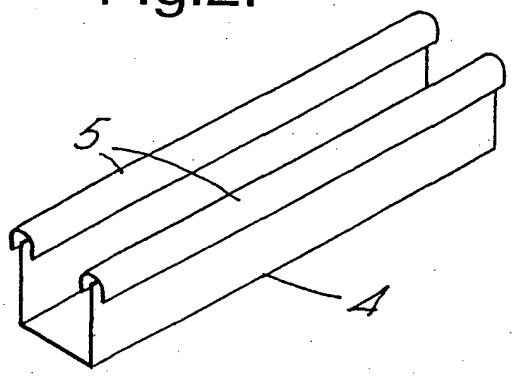
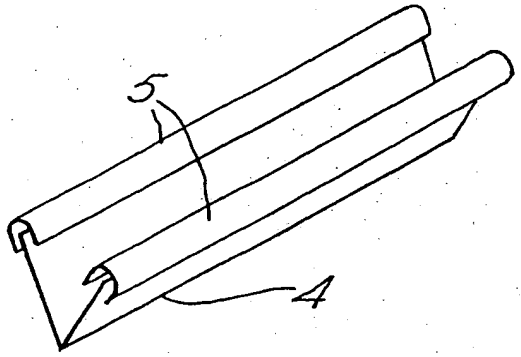


Fig.3.



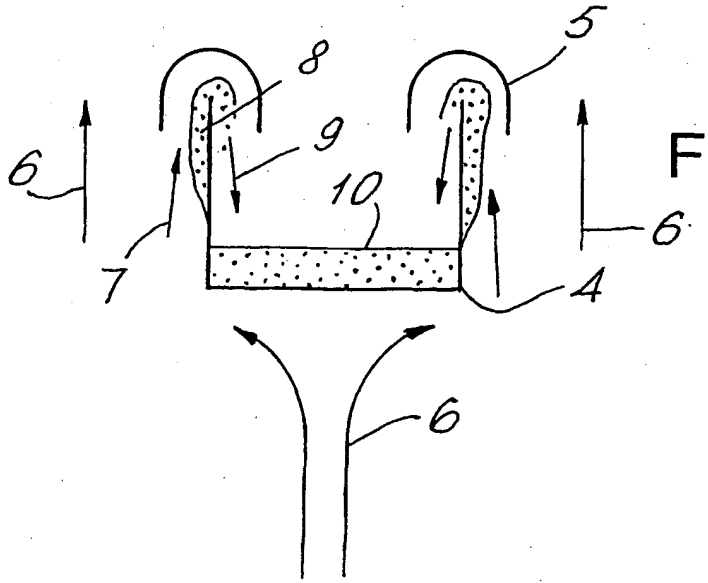


Fig.4.

Fig.5.

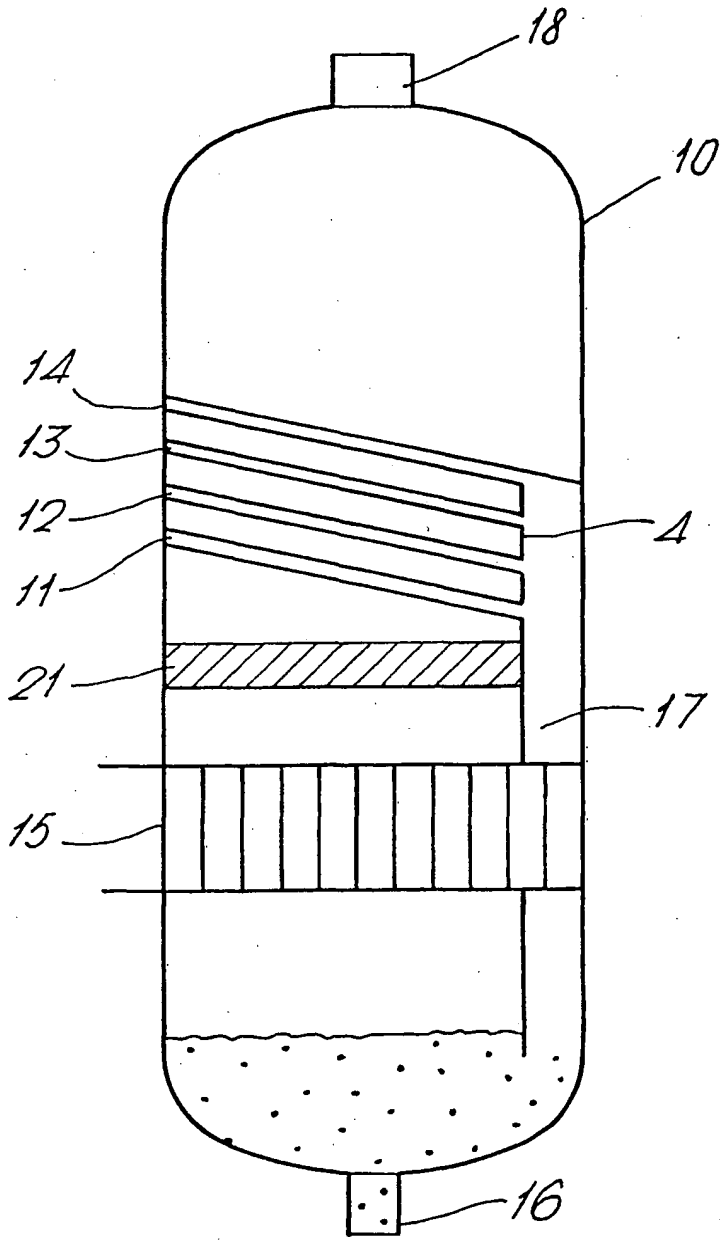
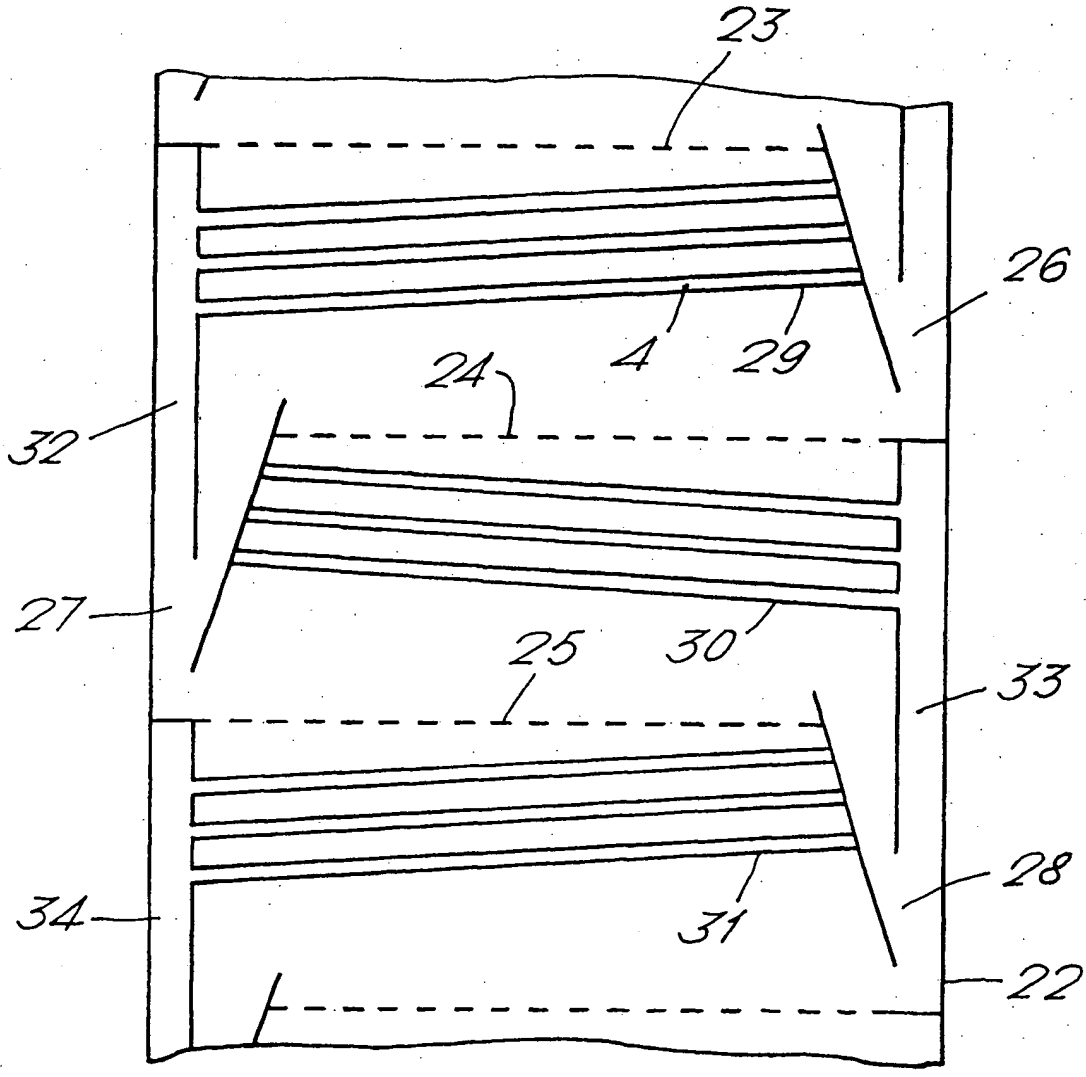


Fig.6.



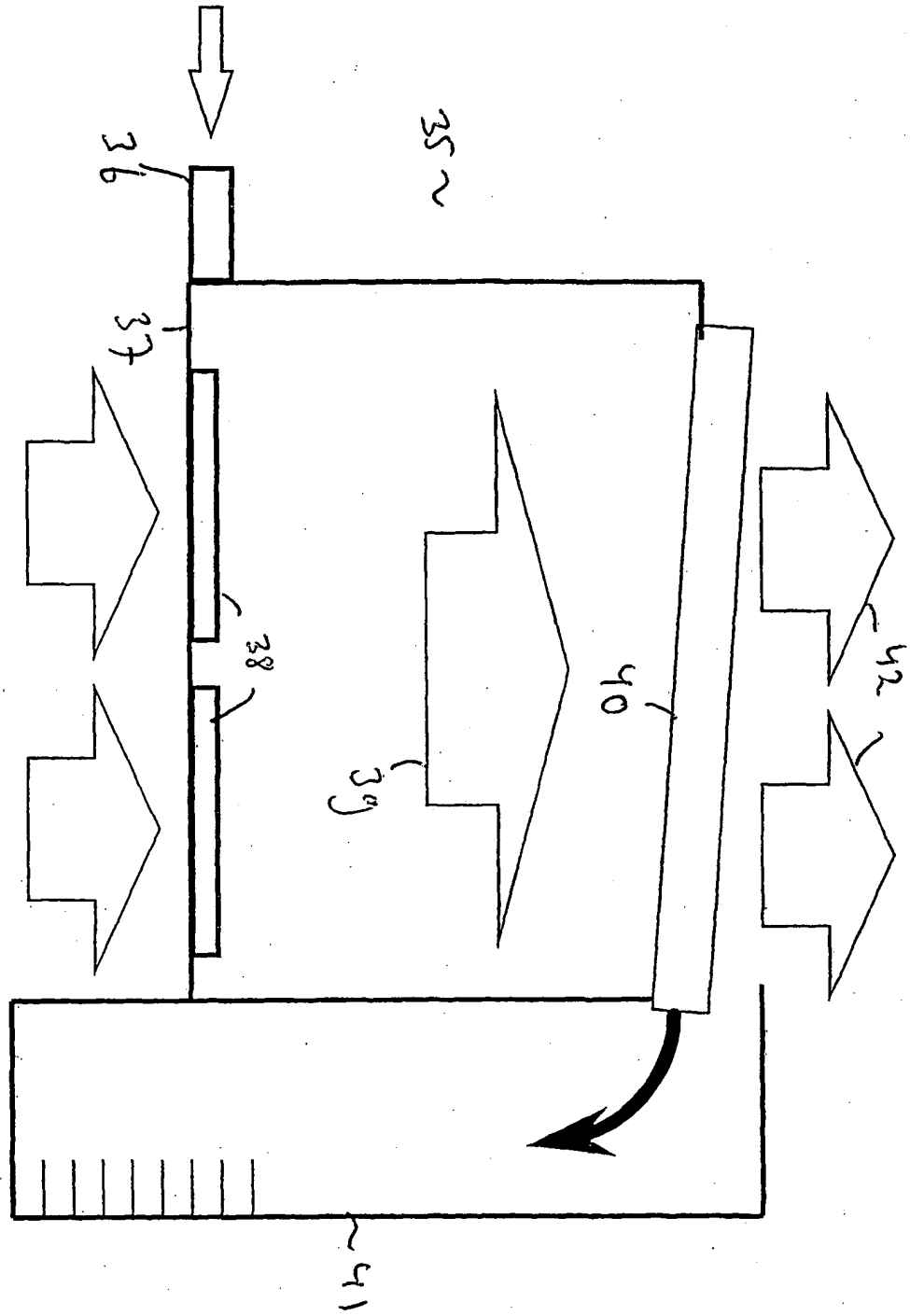


Fig. 7

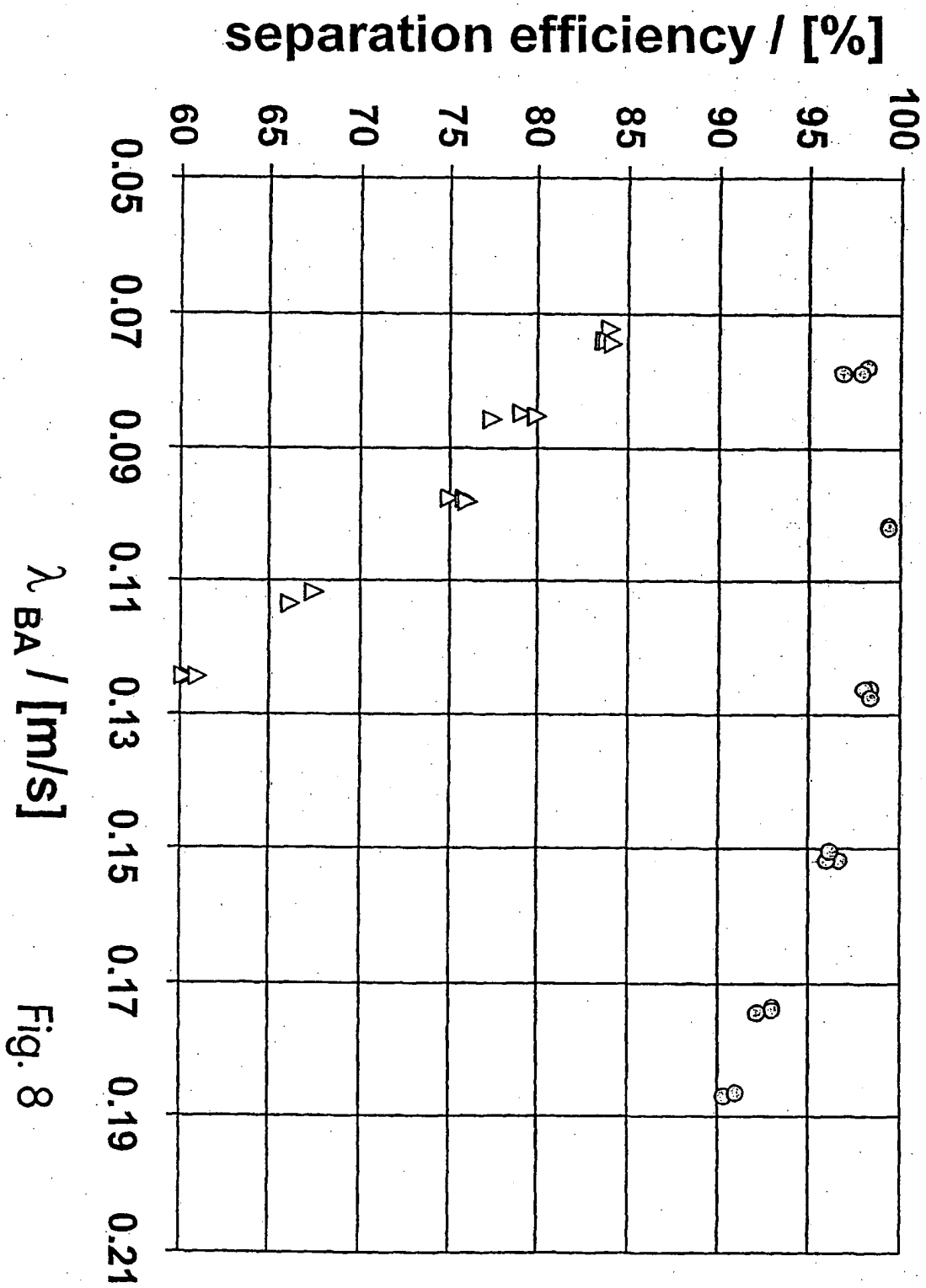
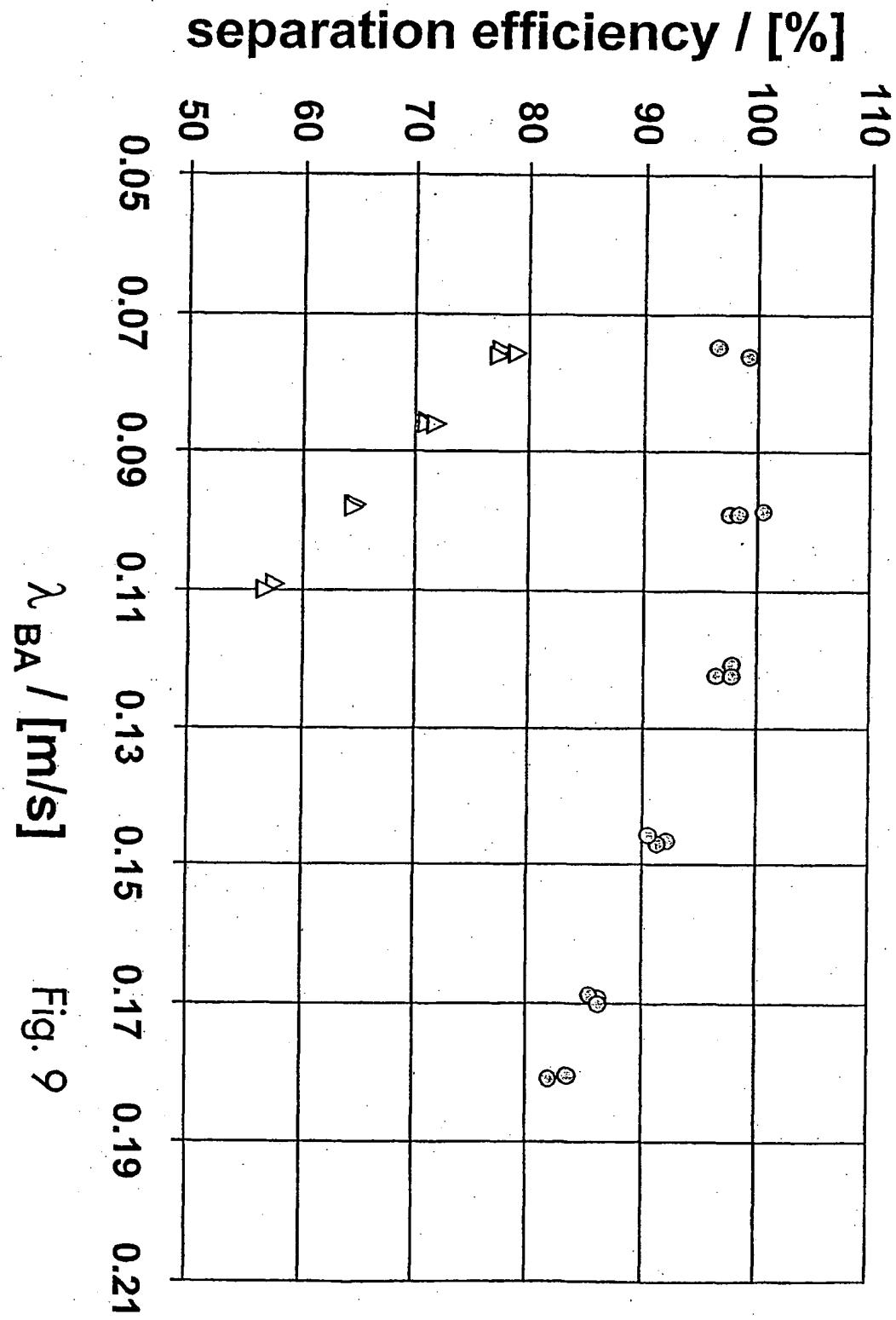

separation efficiency / [%]
60
65
70
75
80
85
90
95
100
0.05
0.07
0.09
0.11
0.13
0.15
0.17
0.19
0.21
λ BA / [m/s]

Fig. 8


separation efficiency / [%]
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60
70
80
90
100
110
0.05
0.07
0.09
0.11
0.13
0.15
0.17
0.19
0.21
λ BA / [m/s]

Fig. 9

INTERNATIONAL SEARCH REPORT

Ir ional Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B01D3/20 B01D53/18 B01D45/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B01D B01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	DD 109 806 A (SCHWARZ) 20 November 1974 (1974-11-20) column 1, line 1 -column 1, line 4 column 3, line 36 -column 4, line 4 ---	1 2,6-8
Y	US 4 361 469 A (TRUTNA) 30 November 1982 (1982-11-30) cited in the application column 3, line 37 -column 6, line 26 ---	2,6-8
X	US 5 683 629 A (KONIJN) 4 November 1997 (1997-11-04) column 2, line 55 -column 3, line 53 ---	1
A	US 6 131 891 A (RESETARITS ET AL) 17 October 2000 (2000-10-17) column 8, line 36 -column 8, line 55 --- -/--	2

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 August 2002	08/08/2002

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Ir ional Application No
PCT/EP 02/03075

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 2 986 233 A (YAP ET AL) 30 May 1961 (1961-05-30) column 2, line 10 -column 3, line 13	2
A	US 4 767 424 A (MCEWAN) 30 August 1988 (1988-08-30) column 4, line 25 -column 4, line 61	4
A	US 4 818 346 A (BENTHAM ET AL) 4 April 1989 (1989-04-04) column 2, line 25 -column 3, line 7	4

INTERNATIONAL SEARCH REPORT

Ir ional Application No
PCT/EP 02/03075

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
DD 109806	A	20-11-1974	DD	109806 A1	20-11-1974
US 4361469	A	30-11-1982	NONE		
US 5683629	A	04-11-1997	AU	690032 B2	09-04-1998
			AU	6189596 A	18-12-1996
			CA	2222623 A1	05-12-1996
			CN	1186451 A ,B	01-07-1998
			DE	69614529 D1	20-09-2001
			DE	69614529 T2	18-04-2002
			DK	828543 T3	08-10-2001
			EA	131 B1	27-08-1998
			WO	9638213 A1	05-12-1996
			EP	0828543 A1	18-03-1998
			NO	975524 A	20-01-1998
US 6131891	A	17-10-2000	NONE		
US 2986233	A	30-05-1961	NONE		
US 4767424	A	30-08-1988	AU	577927 B2	06-10-1988
			AU	5421286 A	16-10-1986
			CA	1286233 A1	16-07-1991
			DE	3662839 D1	24-05-1989
			DK	95986 A	06-09-1986
			EG	17664 A	30-03-1991
			EP	0195464 A1	24-09-1986
			JP	1839666 C	25-04-1994
			JP	5054365 B	12-08-1993
			JP	61204017 A	10-09-1986
			NO	860784 A ,B,	08-09-1986
			NZ	215346 A	31-03-1987
US 4818346	A	04-04-1989	EP	0244896 A2	11-11-1987